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CLIMATE CHANGE VULNERABILITY ASSESSMENT. A FRAMEWORK FOR URBAN PLANNING PRACTITIONERS IN ILALA DISTRICT, DAR ES SALAAM CITY, TANZANIA

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Abstract:
Global climate change is an undisputable challenge in the intervening time. The Global South countries are the most vulnerable to global climate change. It is indicated by the prevalence of climate hazards, including extreme temperatures leading to urban heat island effects(UHI, prolonged droughts, melting of ice caps, increased extreme weather events such as tropical cyclones, heat waves, urban flooding, sea level rise, and coastal erosion resulting in salty water intrusion into freshwater aquifers. This paper explores a framework for climate change vulnerability assessment in the urban planning process in cities of the Global South. A sample of 95 households was selected purposely for the study. Data collection methods involved interviews with structured questionnaires, surveys, focused group discussions, observations, and documentary reviews. Quantitative data analysis was done using a statistical package for social sciences. Qualitative data were analyzed using content, narrative, and interpretive phenomenological analysis. Results showed that climate change physical infrastructures, socioeconomic activities, livelihoods, and ecosystems were vulnerable to climate change-induced flooding in urban areas. The study concludes that adopting a new urban planning process enhances resilience and sustainable cities and communities in cities of the Global South.

Keywords: Climate Change, Vulnerability Assessment, Urban Planning Process, Urban Planning Practitioners, Tanzania

INTRODUCTION

Climate change is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes (Masson-Delmotte et al., 2021). Global climate change impacts such as extreme temperatures leading to urban heat island effects (UHI), prolonged droughts, melting of ice caps, increased extreme weather events, namely tropical cyclones, heat waves, urban flooding, sea level rise, and coastal erosion resulting in salty water intrusion into freshwater aquifers are prevalent in cities (IPCC, 2014; Pauleit et al., 2015). Global climate change impacts severely affect Cities along the coast (Brown et al., 2011; Dodman et al., 2011). The current state of climate shows that greenhouse gas concentrations have escalated due to human activities accounted for 95% (IPCC, 2019; Masson-Delmotte et al., 2021). Future climate projections indicate that global surface temperature, global mean sea level rise, increased precipitation and extreme weather events will increase, and half of the world's population in 2050 will be in cities (Živković, 2019).

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In the Global South of Sub-Saharan African cities, climate change impacts result in damage to socioeconomic activities and livelihoods, increase in urban heat island effects and energy consumption for cooling, destruction of physical infrastructures especially roads, bridges, stormwater drainage systems, power utilities, car parks, transport systems and ecosystem degradation including mangroves, coral reefs and beach erosion (Gombe et al., 2017; Nyashilu et al., 2023; Pauleit et al., 2015). Climate change vulnerability assessment is a practical, responsive tool for adaptation to climate change in various systems, including urban planning (Dhar & Khirfan, 2017). Climate change adaptation planning in urban planning informed by vulnerability assessment involves adjusting the conventional planning paradigm to integrate vulnerability assessment into the planning process. This responds to actual or expected climate change impacts and enhances cities' resilience to climate change (IPCC, 2014).

Despite multiple climate change vulnerability assessment frameworks, there is yet to be a vulnerability assessment (VA) framework for urban planning practitioners in developing countries, including Tanzania. No one size fits all, but it depends on the context of the study (IPCC, 2007b; Schneiderbauer et al., 2020). Many studies show different aspects of consideration in the VA framework, but their focus is on something other than designing a vulnerability assessment framework for urban planning. For example, a study on Spatial-Explicit Climate Change Vulnerability Assessments Based on Impact Chains in Burundi focused on the causal-effect relationship between climate change impacts on water and soil resources by considering three components, namely exposure, sensitivity and adaptive capacity (Schneiderbauer et al., 2020). The study focused on something other than developing a climate change vulnerability assessment framework for urban planning for cities' resilience to climate change rather than water and soil resources.

Furthermore, a study on Climate Change Vulnerability Assessment and Adaptation in Bangladesh focused on income and illness as a driving force of Vulnerability in the health discipline rather than designing a framework for supporting climate change vulnerability assessment in the urban planning discipline (Younus & Kabir, 2018). On the other hand, a study on "Social Vulnerability Induced Floods in Dar es Salaam City, Tanzania" focused on assessing the social Vulnerability of households and communities to climate change-induced floods by understanding the nature of Vulnerability of households following the increased incidences of climate change-induced flooding hazards in most of the cities of developing countries not on developing a framework of vulnerability assessment in urban planning (John, 2015). Mbuya studied the vulnerability analysis of building structures to floods in Dar es Salaam City to analyze the Vulnerability of building structures in informal settlements to floods and associated coping strategies (Kikwasi & Mbuya, 2019). The study should have focused on the context of providing a vulnerability assessment framework for urban planning to enhance resilience and sustainable cities and communities in urban areas. The study on "Vulnerability of human settlements to flood risk in the core area of Ibadan metropolis, Nigeria proposed a flood vulnerability assessment framework for flood risk in a traditional community in the heart of Ibadan metropolis, in the context of their household's exposure, susceptibility and coping capacity ."However, this framework needed to be embedded in guiding climate change vulnerability assessment in the urban planning process for the resilience of cities and communities in urban areas. Ullah (Ullah, 2016) studied the climate change vulnerability of Pakistani towards natural disasters, namely floods, cyclones, droughts and landslides, focused on the aspects of Vulnerability such as social, economic, environmental, physical, political and geographical in terms of exposure, sensitivity and adaptive capacity as crucial factors which determine Vulnerability of a system. The study should have focused on developing a climate

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change vulnerability assessment framework for urban planning practitioners that must address hazards, elements at risk, adaptation capacity assessment and determination of vulnerability levels.

In this regard, this paper explores a framework for climate change vulnerability assessment in the urban planning process of cities in the Global South. Specifically, the study examines climate hazards prevalent in the study area, assesses the elements at risk of climate hazards, assesses adaptation capacity to climate hazards, analyzes the levels of Vulnerability to climate hazards, proposes a new urban planning process, and recommends policy actions for the adoption of the new urban planning process for resilient, and sustainable cities, and communities in the Global South as enhanced as recommended by UN 2030 sustainable development goals 11 (sustainable cities and communities) and 13 (climate action), Agenda 2063 on the Future Africa We Want, the Paris Agreement 2015, the New Urban Agenda 2016 and the Sendai Framework on the Disaster Risk Reduction 2015-2030. In the climate change adaptation planning process, integration of climate change vulnerability assessment in urban development policies, plans and programs such as the city master plans is of paramount importance for enhancing resilience and sustainable cities and communities in urban areas (UN-Habitat, 2014, 2017; UN, 2015c, 2015a; UN, 2015b).

Theoretical Framework. This paper is built on theories about climate change, modern urban planning, including smart cities, ecological cities and slow cities, theory of change, Vulnerability, mainstreaming and adaptation planning (Füssel & Klein, 2006; Leary et al., 2013; Nyashilu et al., 2023; Rysz & Mazurek, 2015). Available studies have defined climate change. The United Nations Framework Convention on Climate Change (UNFCCC) defines *climate change* as a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods (United et al. on Climate Change, 1992). The UNFCCC definition distinguishes between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes such as volcanic eruptions and earthquakes. The Intergovernmental Panel on Climate Change (IPCC) and the World Meteorological Organization (WMO) define climate change as refers to a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and the variability of its properties, and that persists for an extended period, typically decades or longer (LI et al., 2015; Masson-Delmotte et al., 2021; Schneiderbauer et al., 2020).

Meanwhile, there is no agreed standard definition of Vulnerability assessment, but various scholars have defined it as the propensity or predisposition to be adversely affected (Feyissa et al., 2018; IPCC, 2000; Villagra□n de Leo□n, 2006). Conversely, the study A Conceptual and Methodological Review" provides that "Vulnerability is the most elusive component of the hazard-vulnerability-coping capacity-risk (losses)-recovery cycle. It needs to be defined as "vulnerability to what" and" Vulnerability to what" at "what scale," to mention the most important aspects"(Villagra□n de Leo□n, 2006). It encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (Schneiderbauer et al., 2020; Timberlake & Schultz, 2019). However, other studies define Vulnerability as the function of exposure, sensitivity and adaptive capacity (IPCC, 2014; Reay et al., 2007). *Vulnerability assessment* identifies and ranks vulnerabilities regarding a system's exposure, sensitivity and adaptive capacity to climate impacts (Schneiderbauer et al., 2020; Timberlake & Schultz, 2019). The study on Methodological Frameworks for Assessing Vulnerability to Climate Change state also states that "If the vulnerability assessment finds the vulnerability of areas after the adaptation and mitigation measures (pro-active adaptation), then that forms the residual vulnerability of the system" Vulnerability assessed without considering any management activities form the Potential

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Vulnerability" of the system or Vulnerability due to impacts." Suppose the vulnerability assessment is done for the present climatic scenario. In that case, it is the Vulnerability due to climate variability," and If Vulnerability is done for a future scenario, it is Vulnerability due to climate change" (IPCC, 2007b). The study concludes that no one-size-fits-all methodology fits all vulnerability assessments, but it depends on the available tools and data (IPCC, 2007b; Yimam & Holvoet, 2022). *Exposure* to climate-related hazards is the location of the elements at risk relative to the occurrence of the climate hazards (LI et al., 2015). The proximity of elements at risk to the location of climate hazards determines their low, medium, and high exposure (Rodríguez & Santos, 2018). Exposure denotes the direct danger or stressor and the nature and extent of the region's climate variables, including temperatures, precipitation, and extreme weather events (Reay et al., 2007). *Sensitivity* is the human-environmental condition that can worsen the hazards, ameliorate the hazard, or trigger an impact (Feyissa et al., 2018). The *potential impact* for the elements at risk of climate-related hazards is the summation of exposure and sensitivity (Schneiderbauer et al., 2020; Tapia et al., 2017). *Adaptive capacity* is the ability often measured in the time it takes for a system to change its structure to support essential system functions in response to perturbation); and its resilience (the rate at which a system regains structure and function following a perturbation) (Feyissa et al., 2018a).

Conceptual Model for Climate Change Vulnerability Assessment Framework. This paper's climate change vulnerability assessment conceptual model encompasses four steps and three sub-steps. The key steps involve assessing climate hazards, assessing elements at risk, assessing adaptation capacity and determining the levels of Vulnerability for the elements at risk to climate flooding hazards, as illustrated in Figure 2.1.

Climate Hazards Assessment. The climate hazard assessment is the first step in assessing Vulnerability to climate change in the system under consideration. It involves analysis of past, current and future climate hazards or impacts in the given system. Climate hazards vary from one point to another. One system might be affected by a rise in sea level and another by droughts, but for this study, it is flooding. The climate hazards assessment criteria are diverse, but for this context, they involved impact severity, frequency of occurrence, the extent of the area affected by flooding hazards, the population affected by flooding hazards, likelihood of occurrence of flooding hazards and duration of occurrence of flooding hazards. Impact severity indicates the degree of damage caused by flooding hazards (Aslam, 2018; Schneiderbauer & Ehrlich, 2004; Younus & Kabir, 2018).

The impact severity criteria are categorized as low for flooding hazards with small change or little loss of lives and properties in the community, medium for flooding hazards with a modest loss of lives and properties to the community, and severe impact severity for flooding hazards with significant change or loss of lives and property in the community. The frequency of flooding hazards is the time they occur in each period. The frequency of flooding hazards was categorized as every year, every two years and every five years. The extent of the area affected by flooding hazards is the spatial scale at which it occurs. The criteria used to assess the extent of the area affected by flooding hazards involved a small part of the ward, a large part of the ward and the whole ward. The population affected by flooding hazards is the number of people affected at the community level. The assessment criteria for the extent of the population affected by flooding hazards were a small part of the community in the ward, a large part of the community in the ward and the whole community in the ward. The likelihood of the flooding hazard is the possibility at which it can occur. The criteria used for assessing the likelihood of occurrence of the flooding hazards were occasional, likely, and very likely with likelihood. The criteria used to assess the duration of the flooding hazards were as follows: The duration of occurrence is the period at which it occurs. The sub-steps

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followed in the assessment of climate hazards are stipulated. Methods used were household interviews and focus group discussions.

The first sub-step was getting household field responses through interviews, observations, and documentary reviews. The second sub-step was ranking of field responses using expert opinion in which field responses were ranked from 0-33 as low and assigned a value category of 1, 34-67 as medium with a value category of 2 and 68-100 as high with an assigned value category of 3. The value category in the context of this study is the number assigned to field responses to rank or categorize the Vulnerability of elements at risk to flooding hazards (Ordóñez & Duinker, 2014; Schneiderbauer et al., 2020). The third sub-step was the normalization of field responses expressed in percentages into unit-less values to determine the level of Vulnerability for the elements at risk. These sub-steps were done as illustrated in the results of the climate hazards assessment section.

Elements at Risk Assessment. The elements at risk assessment is the second step in the Vulnerability to climate hazards. It involves analysis of various elements at risk of climate hazards, such as socioeconomic activities and livelihoods, physical infrastructures, ecosystems, and heritage sites. Risk is the probability of harmful consequences that lead to causalities, damaged properties, livelihood loss, and socioeconomic and environmental destructions resulting from interactions between natural or human-induced hazards and vulnerable conditions (IPCC, 2007a; Schneiderbauer & Ehrlich, 2004). It is a function of exposure, sensitivity, potential impacts or hazards and Vulnerability (Bles et al., 2016; IPCC, 2007a; Villagra□n de Leo□n, 2006). In undertaking elements at risk assessment, the criteria for assessment involve exposure, sensitivity, and potential impacts. The potential impact is the potential occurrence of a hazard driven by exposure and sensitivity (Schneiderbauer et al., 2020). Under elements at risk assessment, similar sub-steps as in climate hazards assessment are applied, as illustrated in the results for the elements at risk assessment section

Adaptive Capacity Assessment. Adaptive capacity or adaptation is the ability often measured in the time it takes for a system to change its structure to support essential system functions in response to perturbation); and its resilience (the rate at which a system regains structure and function following a perturbation) (Adger, 2003; Feyissa et al., 2018a; Schneiderbauer et al., 2020). The adaptive capacity of a system is determined in terms of knowledge, wealth, assets, social networks, information, infrastructures, technology, institutions and economy or finance available to the system of study (Derbile, 2017; Feyissa et al., 2018a). The criteria for adaptive capacity assessment consist of knowledge, technology, institutional and economy/finance (Kiunsi, 2013; Schneiderbauer et al., 2020). Adaptation capacity assessment adopts sub-steps, such as climate hazards and elements at risk assessment, as illustrated in the adaptive capacity assessment section results.

Determination of the Vulnerability Levels. The fourth and last step in vulnerability assessment is to determine the elements' vulnerability levels to climate hazards. This step involves the following formula, adopted from Juan and modified to fit the study's context (Villagra□n de Leo□n, 2006).

$$LV = \frac{HRR \text{ x } ERR}{ACR}$$

Whereby

- LV - Level of Vulnerability
- HRR - Hazard Risk Rating
- ERR - Elements at Risk Rating
- ACR - Adaptive Capacity Rating

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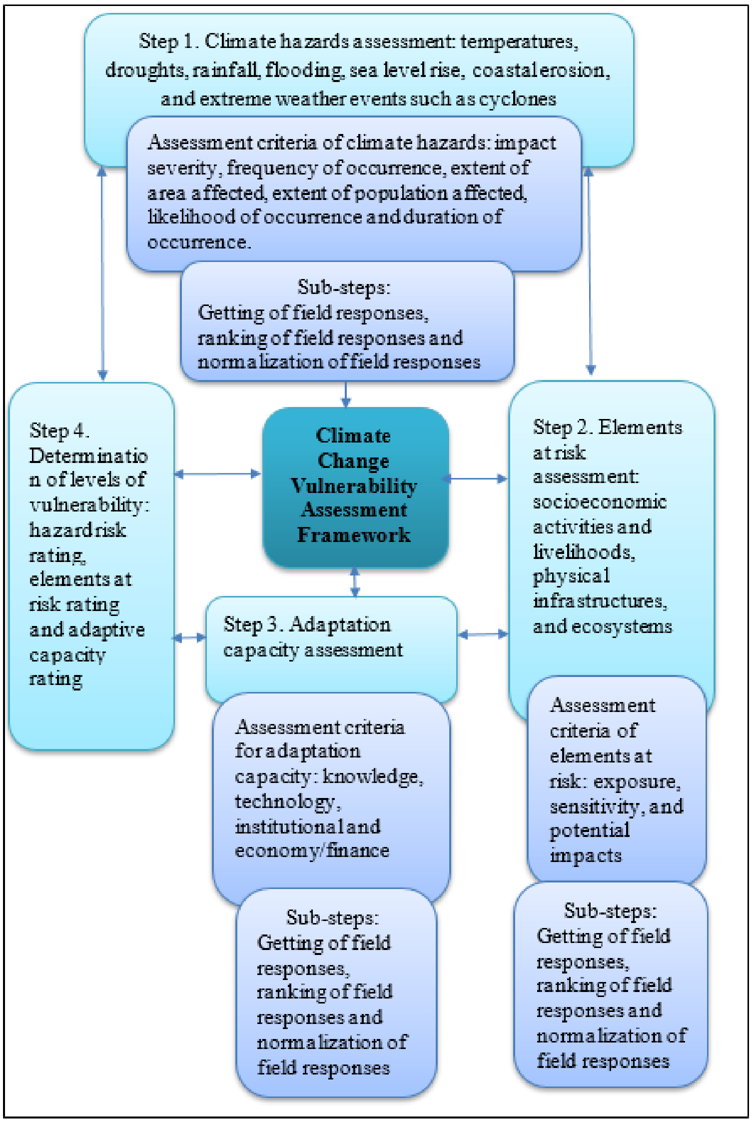
Unlike other steps, vulnerability assessment involves eight sub-steps to determine the level of Vulnerability of elements at risk of climate hazards. This depends on the previous steps of climate hazards assessment, elements at risk assessment and adaptive capacity assessment. Determining the level of Vulnerability required identifying the type of hazards, hazards risk rating, elements at risk rating or potential impacts, adaptive capacity rating, ranking the level of vulnerabilities and results of the vulnerability assessment.

Urban Planning Process. Conventional or traditional urban planning processes involve a preparatory planning phase, a planning phase, an implementation phase and monitoring and review. The preparatory planning phase focuses on stakeholder analysis, problem formulation, setting goals and objectives, inventorying data for planning and analyzing data gathered using scientific methods such as statistical packages for social sciences (SPSS) and GIS (Kasala, 2015).



Source: Framework

Figure 1. Conceptual Model for Climate Change Vulnerability Assessment, 2023

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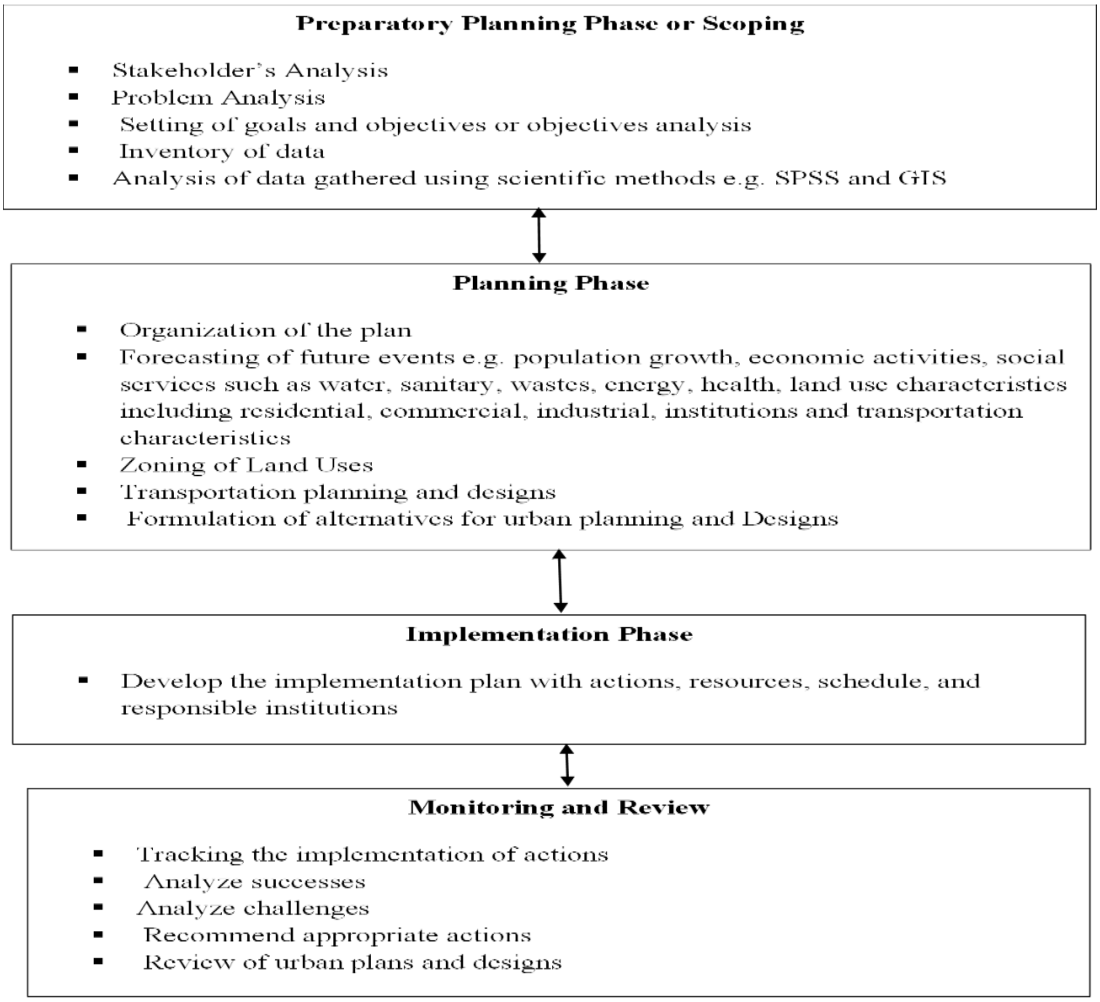
The planning phase focuses on the organization of the plan, forecasting of future events, including population growth, economic activities, social services such as water, sanitary, wastes, energy, health, land use characteristics including residential, commercial, industrial, institutions and transportation characteristics; formulation of alternative urban plan designs. The implementation phase develops the plan with actions, resources, schedules, and responsible institutions. The monitoring and review phase focuses on tracking the implementation of actions regarding successes and challenges and recommends appropriate actions for reviewing urban plans and designs (Kasala, 2015). Figure 2 shows the traditional urban planning process without consideration of climate change adaptation planning.



Source: (URT, 2016a; URT, 2007) and modified

Figure 2. The traditional urban planning process does not consider climate change adaptation planning.

METHODS

The Study Area and Population. The study area is Jangwani ward, Ilala district in Dar es Salaam city. Jangwani ward was sampled because of its exposure to Msimbazi Valley, which puts it at higher risk and Vulnerable to climate change-induced flooding that affects socioeconomic activities and livelihoods, physical infrastructures, and ecological systems. Map 1 shows the location

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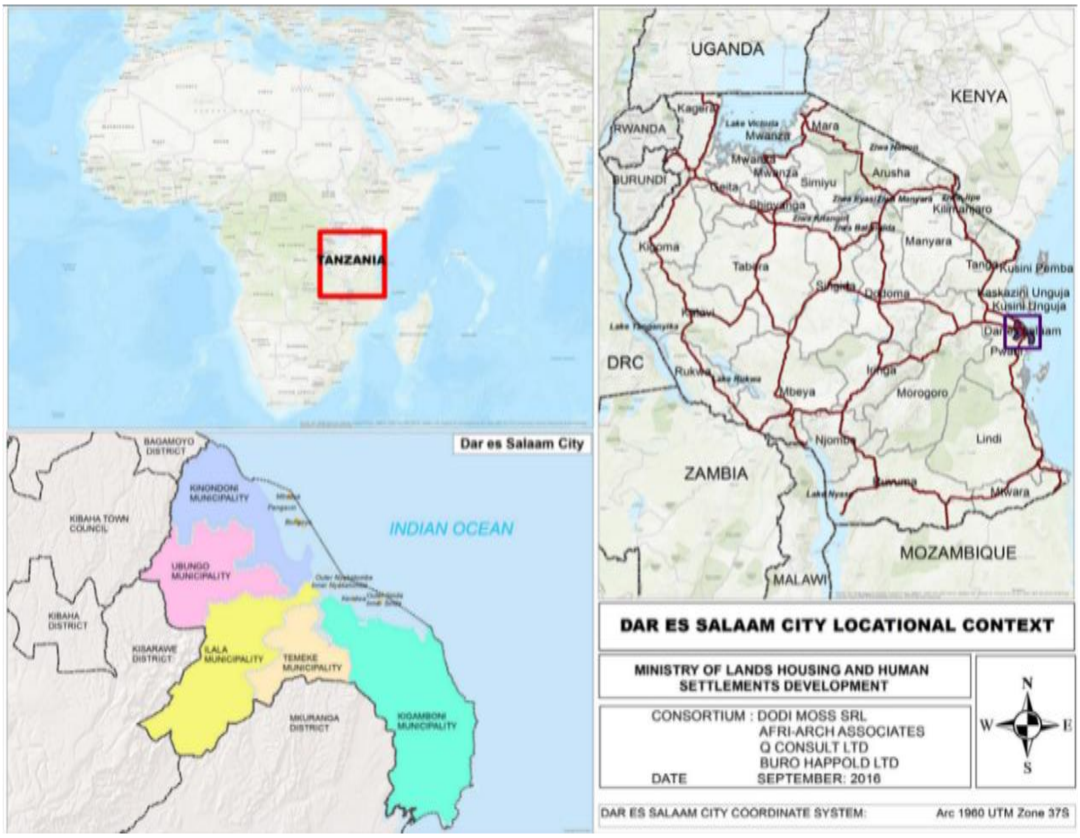
of Tanzania around the globe and the Jangwani ward in Dar es Salaam. Jangwani ward, as per the 2012 housing census report, had a population of 17,647, of which 9,174 were male and 8,473 were female, with several households of 4,190 and sex ratios of 108 (NBS, 2012).



Source: (URT, 2016)

Figure 3. The location of Dar es Salaam city in a national setting

Study Strategy, Sample Size, Data Collection Methods, and Analysis. The study used a mixed research strategy (Yin, 2014, 2016). The study adopted a purposeful sampling method by selecting the Janwani ward in Ilala district, Dar es Salaam city. A sample size of 95 households out of 17,647 were selected purposely for household interviews. Focused Group Discussion (FGD) was conducted with 7 people, of which 3 were women and 4 men. The study collected quantitative and qualitative data through library and field research. Quantitative and qualitative data were at risk due to climate change-induced flooding, including socioeconomic activities, livelihoods, physical infrastructures, and ecosystems. These were collected using household interviews, FGD, surveys, observations, key informant interviews by structured questionnaires and documentary review. Quantitative data were analyzed using IBM SPSS Statistics 20 and Microsoft Excel. Qualitative data were analyzed by content analysis, narrative analysis, and interpretive phenomenological analysis (IPA). The topics for FGD focused on the climate change vulnerability assessment framework, especially on climate hazards affecting the communities, elements at risk and adaptation capacity to climate change. The key informant interviews were conducted with three extraordinary people: the Ward Chairman, one Mtaa Chairwoman and one Mtaa Chairman with history and experience in climate change impacts, Vulnerability and adaptation in the Jangwani ward.

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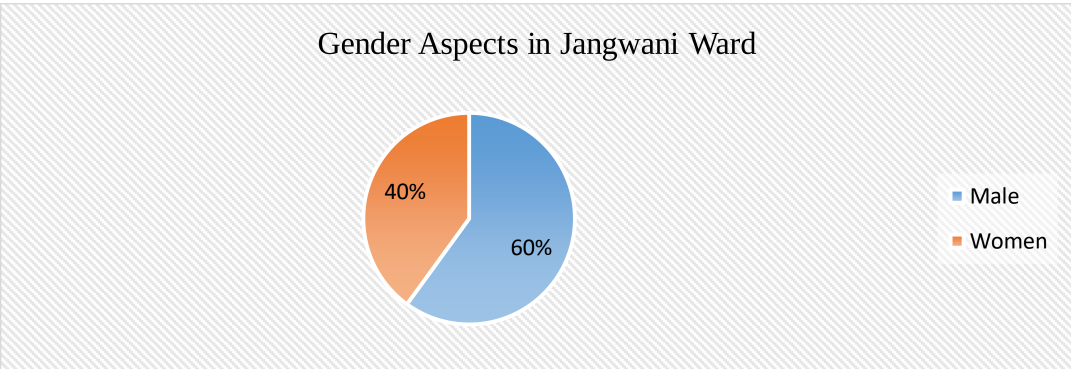
RESULT AND DISCUSSION

Climate Change Vulnerability Assessment in Jangwani Ward. Climate change vulnerability assessment in the ward was used to collect data to determine the Vulnerability to climate flooding hazard level for the elements at risk. The assessment considered four steps and three sub-steps, as stipulated earlier. The steps involved were climate hazards assessment, elements at risk assessment, adaptation capacity assessment and determination of the level of Vulnerability for the elements at risk of flooding. The sub-steps in each step were getting the field responses, ranking field responses and normalization of field responses. The assessment criteria for hazard assessment involved impact severity, frequency of occurrence of flooding hazard, the extent of the area affected, the extent of the population affected, likelihood of occurrence and duration of occurrence of the flooding hazard. The elements at risk involved were socioeconomic activities and livelihoods, namely housing, urban farming, informal businesses or petty trade, and construction; physical infrastructures, namely roads, bridges, car parks, stormwater drainage systems, electric power lines, and Bus Rapid Transit (BRT) central station; and ecosystems namely beaches, mangroves and coral reefs, green open spaces, and public open spaces. The assessment criteria for the elements at risk were exposure, sensitivity, and potential impacts. The assessment criteria for adaptation capacity to flooding hazards involved knowledge, technology, institutional and economy/finance. The determination of the level of Vulnerability involved hazard risk rating, elements at risk rating and adaptation capacity rating.

Demography and Gender. The study was conducted on 95 people from the same number of households in the Jangwani ward. The results of the household interviews in Figure 4 indicate that 60% of the interviewed people were men and 40% were women.



Source: Field data, 2021

Figure 4. Gender aspects in the study ward

Climate change hazard assessment. The climate change hazard assessment involved assessing flooding hazards in the ward in terms of impact severity, frequency of occurrence, the extent of the area affected, the extent of the population affected, the likelihood of occurrence and duration. This was done following the sub-steps below.

Getting the Field Responses on Flood Hazard Assessment. The first sub-step involved getting household field responses through interviews and focused group discussions. The critical questions involved the level of effects, frequency of occurrence, area and population affected, and likelihood and duration of flooding occurrences. The potential impact was calculated by summation of the exposure and sensitivity.

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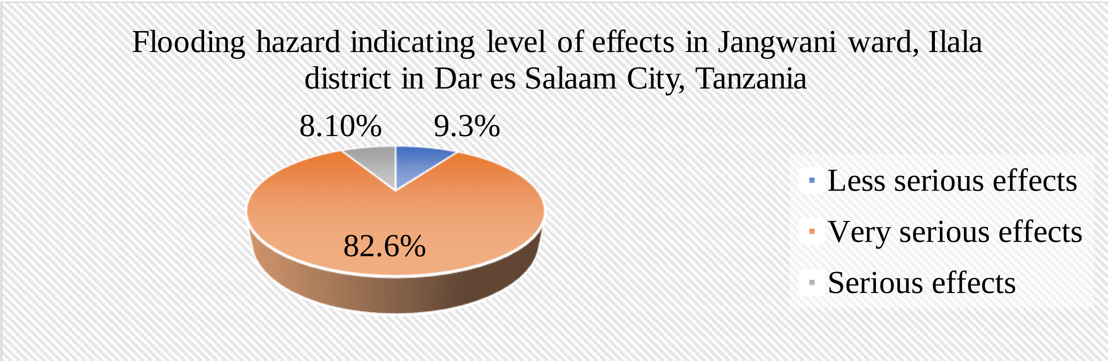
Level of Effects of Flooding Hazard. The analysis results in Figure 5 on the effects of flooding hazards in the Jangwani ward show that 82.6% of the respondents responded that flooding has severe effects, 8.1% responded with serious effects, and 9.3% responded that flooding has less severe effects in the ward.



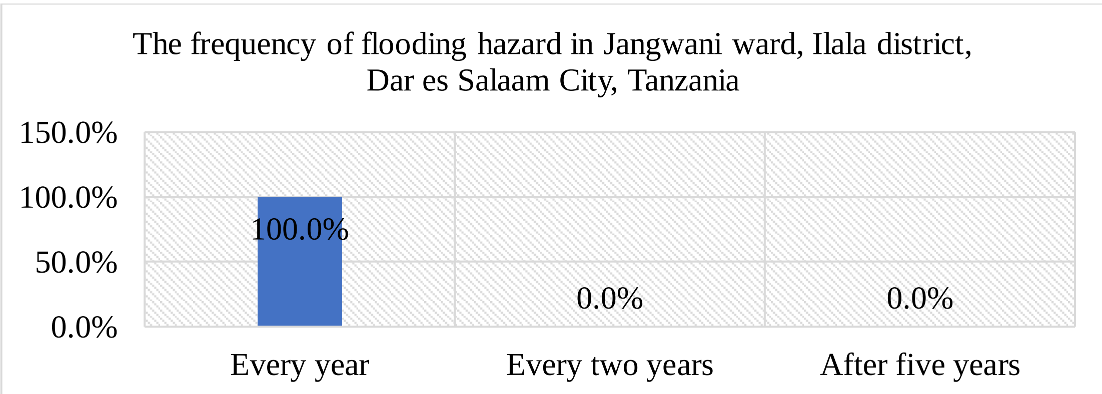
Source: Field data, October 2021

Figure 5. Field responses of the effects of flooding hazard in Jangwani Ward

The Frequency of Occurrence of Flooding Hazard. The results of the analysis in Figure 4.2 indicate that 100% of the respondents reported the frequency of the flooding hazard occurrence every year, and 0% reported the occurrence of the flooding hazard every two years and after five years.

The Extent of the Area Affected by Flooding Hazard. The analysis results in Figure 4.3 show that the whole ward was affected by flood hazards, accounting for 66.6%, a large part of the ward 24.4% and a small part of the ward 9.0%.

The Extent of the Population Affected by Flooding Hazard. The analysis results in Figure 4.4 show that the whole community in the ward was affected by flood hazards, accounting for 55.5%, a small part of the community in the ward 13.7% and a large part of the community in the ward 30.8%.



Source: Field data, October 2021

Figure 6. Field responses to the frequency of flooding hazards in the Jangwani ward.

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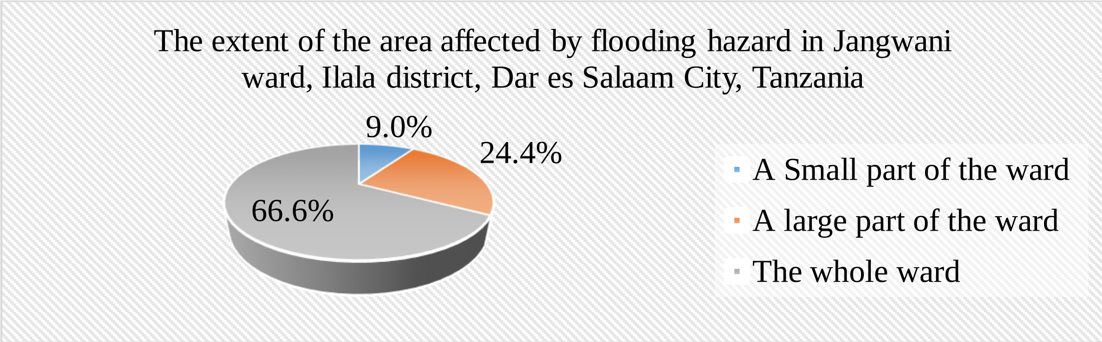
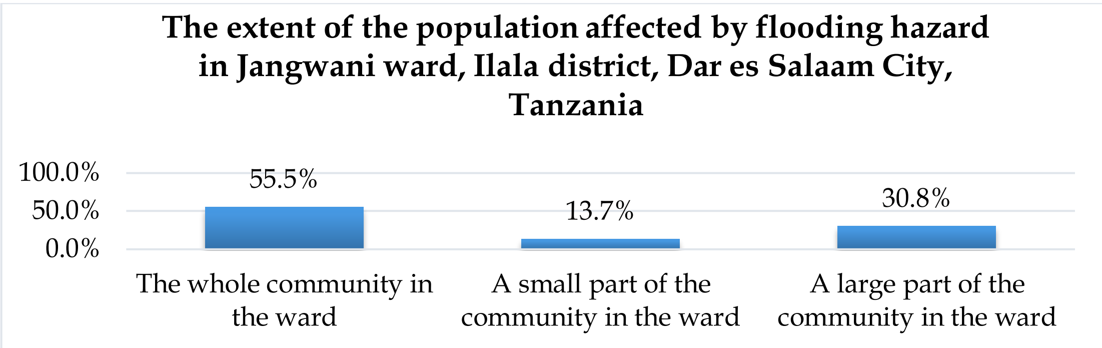


Source: Field data, October 2021

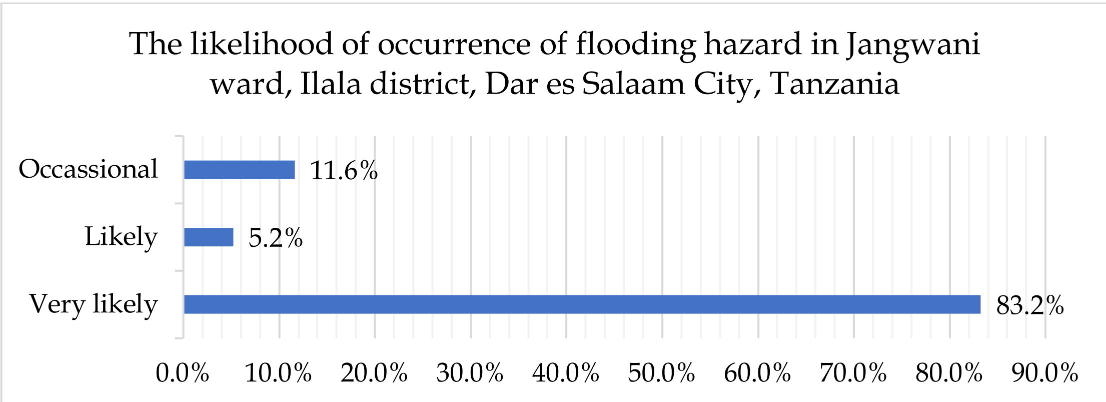
Figure 7. Field responses of the extent of the area affected by flooding in Jangwani ward

The Likelihood of Occurrence of Flooding Hazard. The analysis results in Figure 9 indicate that the likelihood of flooding in the Jangwani ward was 83.2%, likely 5.3% and occasionally 11.6%.



Source: Field data, October 2021

Figure 8. Field responses of the extent of the area and population affected by flood hazard in Jangwani Ward.



Source: Field data, October 2021

Figure 9. Field responses of the likelihood of occurrence of flood hazard in Jangwani ward

Duration of Occurrence of Flooding Hazard. The analysis in Figure 10 indicated that 86.3% of the duration of the occurrence of flood hazards occurred for days, 10.5% for weeks, and 3.2% for hours.

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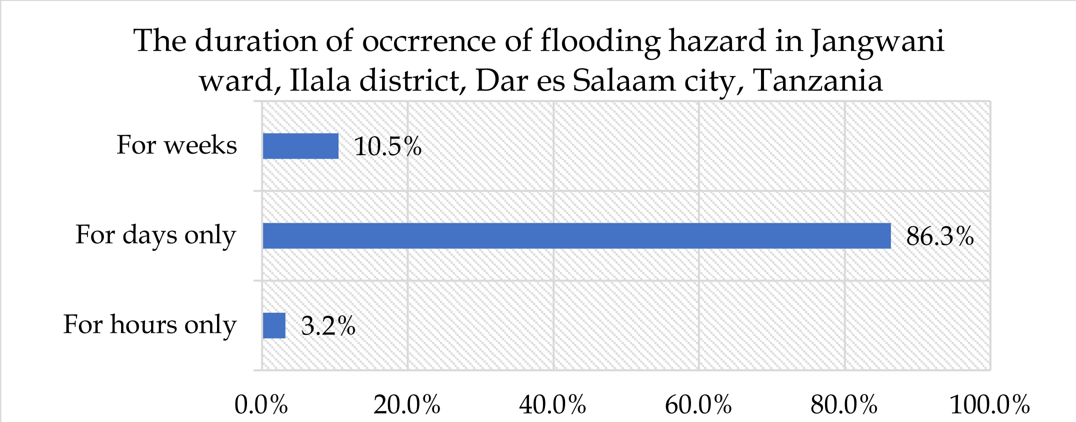

Source: Field data, October 2021

Figure 10. Field responses of the duration of occurrence of flood hazard in Jangwani ward

Ranking of Field Responses. The second sub-step was ranking field responses. The field responses were ranked for all hazard assessment parameters. The impact severity of flooding climate hazards was ranked low, medium, and high. The categories and their values are shown in Table 4.1, where (0-33) is low severity, (34-67) is medium severity, and (68-100) is severe severity. This ranking system applies to other parameters as described below.

Table 1. Ranking of field responses into categories

Response in %	Severity category	Value
0-33	Low severity	1
34-67	Medium severity	2
68-100	Serious severity	3

Source: Author's Construct 2023

Normalization of Field Responses. The third sub-step was to convert field responses into pre-determined categories and values, or normalization. Tables 2, 3, 4, 5, 6 and 7 show the normalization of field responses to pre-determined categories and values of the parameters. The overall impact severity was determined by summing up the category values in each ward, 2.7. This sub-step also applies to other parameters as described.

Table 2. The normalization of field responses to pre-determined categories

Impact severity	Field responses (%)	Value category	Field response/100 x value category
Less serious impact	9.3	1	0.1
Serious impact	8.1	1	0.1
Very serious	82.6	3	2.5
Overall Value		2.7	

Source: Author's Construct 2023

Table 3. The normalization of field responses of frequency of occurrence to pre-determined categories.

Frequency of occurrence	Field responses (%)	Value category	Field response/100 x value category

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Every year	100	3	3
Every after Two Years	0	1	0
Every after Five Years	0		0
Overall Value		3	

Source: Author's Construct 2023

Table 4. Normalization of field responses for the extent of the area affected by flooding hazards into pre-determined values, 2023

The extent of the area affected	Field responses (%)	Value category	Field response/100 x value category
A small part of the ward	9.0	1	0.1
A large part of the ward	24.4	1	0.2
The whole ward	66.6	2	1.3
Overall Value		1.6	

Table 5. Normalization of field responses for the extent of the area affected by flooding hazards into pre-determined values, 2023

The extent of the population affected	Field responses (%)	Value category	Field response/100 x value category
A small part of the community ward	13.7	1	0.1
A large part of the community in the ward	30.8	1	0.3
The whole community in the ward	55.5	2	1.1
Overall Value		1.5	

Table 6. Normalization of field responses for the likelihood of occurrence of flooding hazards into pre-determined values, 2023

Likelihood of occurrence	Field responses (%)	Value category	Field response/100 x value category
Occasional	11.6	1	0.1
Likely	5.2	1	0.1
Very likely	83.2	3	2.5
Overall Value		2.7	

Table 7. Normalization of field responses for the likelihood of occurrence of flooding hazards into pre-determined values, 2023

Duration of occurrence	Field responses (%)	Value category	Field response/100 x value category
For hours only	3.2	1	0.1
For days only	86.3	1	0.1
For weeks only	10.5	3	2.5
Overall Value		2.7	

Table 8 indicates the average values of the climate hazard assessment. The average value for the flooding hazard assessment is 2.4, which will be used to determine the vulnerability levels as a hazard risk rating.

Table 8. The average values of flooding hazard assessment in Jangwani ward, 2023

Climate hazard assessment parameters	Overall values

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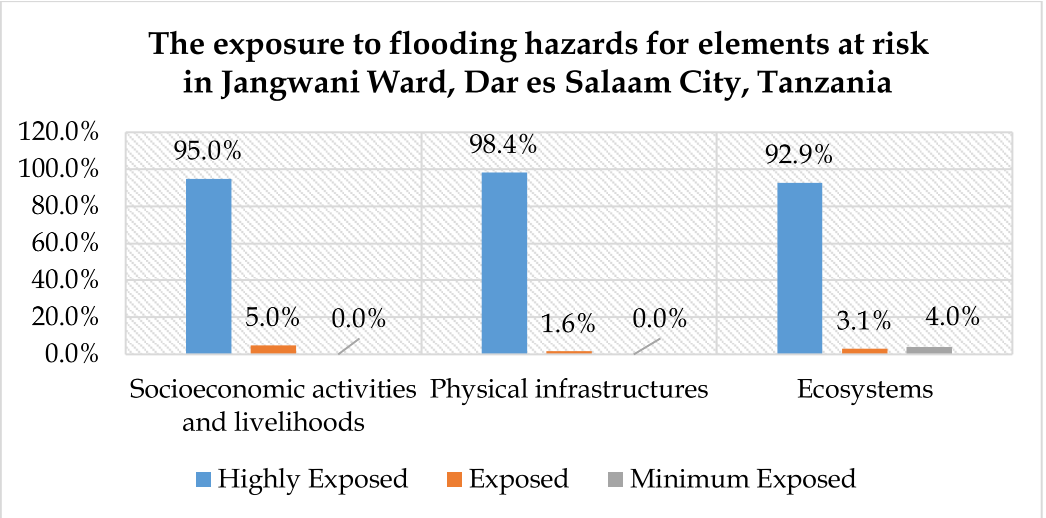
Impact severity	2.7
Frequency of occurrence	3
The extent of the area affected	1.6
The extent of the population affected	1.5
Likelihood of occurrence	2.7
Duration of occurrence	2.7
Average values	2.4



Source: Field data, October 2021

Figure 11. The Exposure to Climate Change Induced Flooding Hazards for Elements at Risk, Namely Socioeconomic Activities and Livelihoods, Physical Infrastructures, and Ecological Systems in Jangwani Ward

Assessment of the Elements at Risk of Flooding Hazard. Obtaining Field Responses. The first step involved obtaining household field responses through interviews and focused group discussions. The key questions involved the exposure and sensitivity of the elements at risk of flooding hazards in the study area. The potential impact was calculated by summation of the exposure and sensitivity.

Exposure to Flooding Hazards. The analysis results in Figure 11 indicate that the exposure to flooding hazards for elements at risk for socioeconomic activities and livelihoods was highly exposed at 95.0%, 5.0% and minimum exposed at 0.0%. The physical infrastructures were highly exposed at 98.4%, exposed at 1.6% and minimum exposed at 0.0%. The ecosystems were highly exposed at 92.9%, 3.1% and minimum % exposed at 4.0%.

Sensitivity to Flooding Hazards. The analysis results in Figure 12 indicate that the sensitivity to flooding hazards for elements at risk for socioeconomic activities and livelihoods was compassionate at 98.9%, sensitive at 1.1% and not sensitive at 0.0%. The physical infrastructures were highly sensitive at 99.0%, sensitive at 1.0% and not sensitive at 0.0%. The ecosystems were susceptible at 90.0%, sensitive at 9.1% and not sensitive at 0.0%.

Potential Impacts of Flooding Hazards. The analysis results in Figure 14 indicate that the potential impacts of climate change-induced flooding hazards for elements at risk for socioeconomic activities and livelihoods were very high 193.9%, high 6.1% and not high 0.0%. The potential impacts of flooding hazards on physical infrastructures were high at 197.9%, high at 12.1% and not high at 0.0%. The potential impacts of flooding hazards on ecosystems were high at 188.8%, 10.2%, and not

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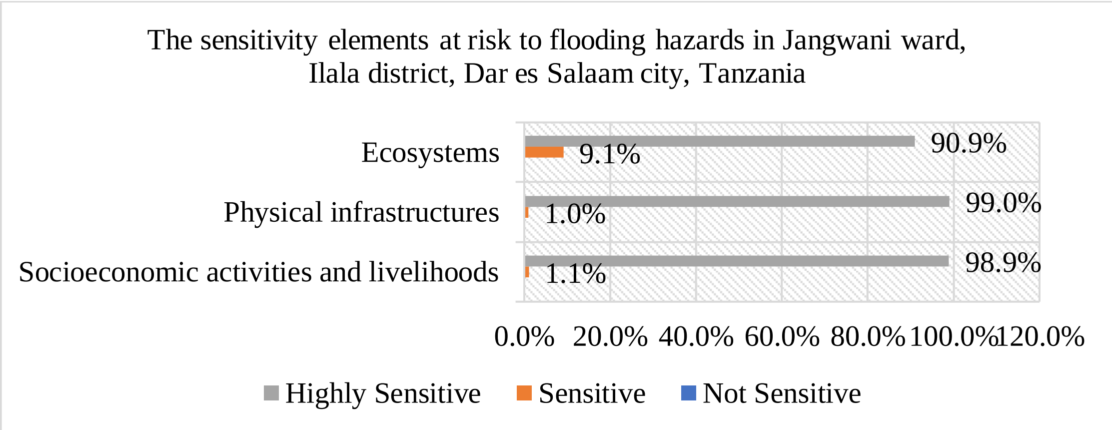
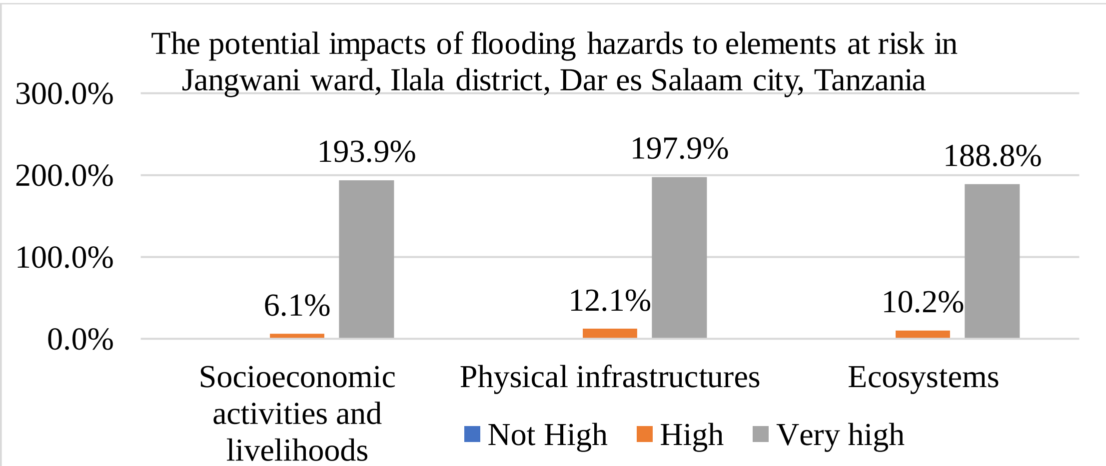
high at 0.0%. Unlike exposure and sensitivity, whose total percentage is one hundred, the total percentage of potential impacts is two hundred because it is the summation of exposure and sensitivity values.

Ranking of Field Responses. The second sub-step was to rank the responses into exposure categories, namely minimum exposed, exposed, and highly exposed, with response categories of 0-33, 34-67, and 68-100 converted or ranked into value scales of 1, 2 and 3, respectively. This ranking system is applied to other parameters as described. The sensitive categories were categorized as not sensitive, minimum sensitive, sensitive, and highly sensitive, with similar response categories. The potential impact values were categorized as not high, high, and very high with response categories of 0-67, 68-134 and 135-200, which were converted into 1, 2 and 3 value scales, respectively. Table 4.9 shows the ranking of exposure, sensitivity, and potential impact.



Source: Field data, October 2021.

Figure 12. The Sensitivity to Climate Change Induced Flooding Hazard for Elements at Risk for Socioeconomic Activities and Livelihoods, Physical Infrastructures, and Ecological Systems in Jangwani Ward



Source: Field data, October 2021

Figure 13. The potential impacts of climate change-induced flooding hazard for elements at risk for socioeconomic activities and livelihoods, physical infrastructures, and ecological systems in Jangwani ward

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Table 9. Ranking of exposure, sensitivity, and potential impact, 2023

Field response (%)	Exposure	Value	Sensitivity	Value	Field response (%)	Potential impact	Value
0-33	Minimum Exposed	1	Not Sensitive	1	0-67	Not high	1
34-67	Exposed	2	Sensitive	2	68-134	High	2
68-100	Highly Exposed	3	Highly Sensitive	3	135-200	Very high	3

Normalization of Field Responses. The third sub-step was to convert field responses into pre-determined categories and values or normalization. Tables 10, 11 and 12 show the normalization of field responses to pre-determined categories and values for the exposure, sensitivity, and potential impacts for the elements at risk.

Table 10. Normalization of field responses for exposure of socioeconomic activities and livelihoods as elements at risk to flooding hazards into pre-determined values, 2023

Exposure	Field responses (%)	Value category	Field response/100 x value category
Minimum exposed	0	1	0
Exposed	1.1	1	0
Highly exposed	98.9	3	3
Overall Value		3	

Table 11. Normalization of field responses of sensitivity of socioeconomic activities and livelihoods as elements at risk to flooding hazards into pre-determined values, 2023

Sensitivity	Field responses (%)	Value category	Field response/100 x value category
Not sensitive	0	1	0
Sensitive	1.1	1	0
Highly sensitive	98.9	3	3
Overall Value		3	

Table 12. Normalization of field responses of potential impacts for socioeconomic activities and livelihoods as elements at risk to flooding hazards into pre-determined values, 2023

Potential impact	Field responses (%)	Value category	Fiel response/200 x value category
Not high	0	1	0
High	2.2	1	0
Very high	197.8	3	3
Overall Value		3	

The overall value 3 of the potential impact of flooding hazards on socioeconomic activities and livelihoods as elements at risk will be used as elements at risk value to calculate the vulnerability levels.

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The sub-steps above for normalization were used for physical infrastructures and ecosystems as elements at risk from flooding hazards. In this regard, Tables 14, 15, and 16 show the normalization of the field responses for exposure, sensitivity, and potential impacts.

Table 13. Normalization of field responses for exposure of physical infrastructures as elements at risk to flooding hazards into pre-determined values, 2023

Exposure	Field responses (%)	Value category	Field response/100 x value category
Minimum exposed	0	1	0
Exposed	1.1	1	0
Highly exposed	98.9	3	3
Overall Value		3	

Table 14. Normalization of field responses of sensitivity of physical infrastructures as elements at risk to flooding hazards into pre-determined values, 2023

Sensitivity	Field responses (%)	Value category	Field response/100 x value category
Not sensitive	0	1	0
Sensitive	1	1	0
Highly sensitive	99	3	3
Overall Value		3	

Table 15. Normalization of field responses of potential impacts for physical infrastructures as elements at risk to flooding hazards into pre-determined values, 2023

Potential impact	Field responses (%)	Value category	Field response/200 x value category
Not high	0	1	0
High	2	1	0
Very high	198	3	3
Overall Value		3	

The overall value 3 of the potential impact of flooding hazards on physical infrastructures as elements at risk will be used as elements at risk value to calculate the vulnerability levels.

Table 16. Normalization of field responses for exposure of ecosystems as elements at risk to flooding hazards into pre-determined values, 2023

Exposure	Field responses (%)	Value category	Field response/100 x value category
Minimum exposed	1	1	0
Exposed	1.1	1	0
Highly exposed	97.9	3	3
Overall Value		2.9	

Table 17. Normalization of field responses of sensitivity of ecosystems as elements at risk to flooding hazards into pre-determined values, 2023

Sensitivity	Field responses (%)	Value category	Field response/100 x value category
Not sensitive	0	1	0
Sensitive	9.1	1	0.1
Highly sensitive	90.9	3	2.7

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Overall Value	2.8

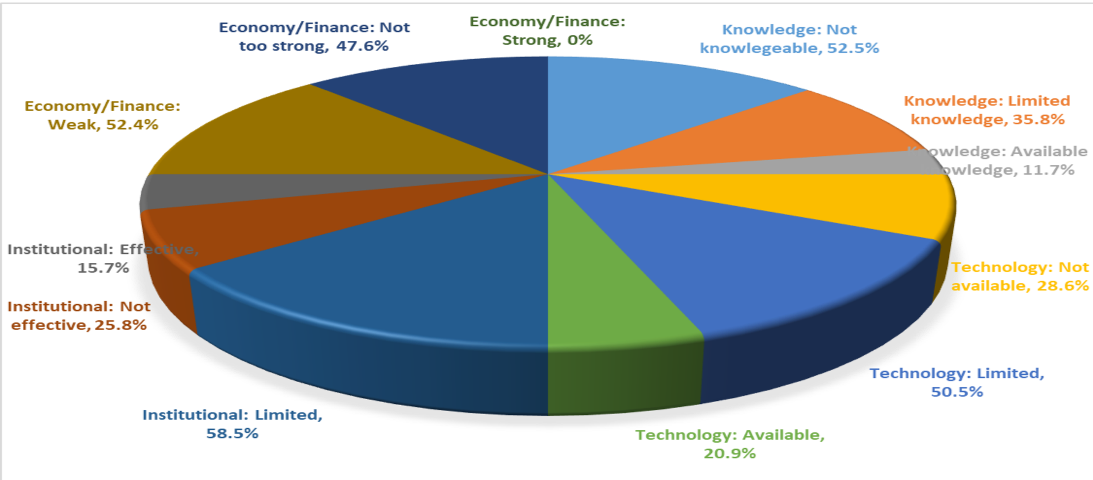
Table 18. Normalization of field responses of potential impacts for ecosystems as elements at risk to flooding hazards into pre-determined values, 2023

Potential impact	Field responses (%)	Value category	Field response/200 x value category
Not high	0	1	0
High	18.2	1	0.1
Very high	181.8	3	2.7
Overall Value		2.8	

The overall value 2.9 of the potential impact of flooding hazards to ecosystems as elements at risk will be used as elements at risk value to calculate the vulnerability levels.

Assessment of Adaptative Capacity to Flooding Hazard. Getting of Field Responses. The first sub-step was to get responses from ministry officials for each parameter through interviews whose results were analyzed. The assessment criteria were knowledge, technology, institutional and economy/finance. The key questions involved the adaptive capacity regarding knowledge, technology, institutional and economy/finance. Figure 14 shows the field responses of interviews with the Ministry of Lands staff. The study results in Figure 14 indicate that the adaptive capacity to climate change hazards, including flooding, was not knowledgeable 52.5%, limited knowledge 35.8% and available knowledge 11.7%. Technology was not available 28.6%, limited technology 50.5% and available technology 20.9%.

Moreover, institutional was limited to 58.5, ineffective at 25.8, and effective at 15.7%. Furthermore, economy/finance was weak at 52.4%, not too strong at 47.6 and robust at 0.0%. The adaptive capacity assessment criteria were presented in one pie chart to compare their results.



Source: Field data, 2021

Figure 14. The adaptive capacity to climate change hazards at the national level

Ranking of Field Responses. The second sub-step was to put the responses into categories of adaptation capacity, namely not knowledgeable, limited knowledge, and available knowledge for knowledge parameter with response categories of 0-33, 34-67 and 68-100, respectively. Regarding

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technology, the response categories for adaptation capacity were unavailable, limited, and available technology, with response categories of 0-33, 34-67 and 68-100, respectively. For institutional, the response categories for adaptation capacity were ineffective, limited, and practical, with response categories of 0-33, 34-67 and 68-100, respectively. On the other hand, for economy/finance, the response categories for adaptation capacity were categorized as weak economy/finance, not too strong economy/finance, and strong economy/finance, with response categories of 0-33, 34-67 and 68-100, respectively. Tables 4.19, 4.20, 4.21 and 4.22 show the ranking of field responses.

Table 19. Ranking of field responses for knowledge

Response in %	Knowledge Category	Numerical Value
0-33	Not Knowledgeable	1
34-67	Limited Knowledge	2
68 -100	Available Knowledge	3

Source: Author's Construct 2023

Table 20. Ranking of field responses for technology

Response in %	Technology Category	Numerical Value
0-33	Not Available Technology	1
34-67	Limited Technology	2
68 -100	Available Technology	3

Source: Author's Construct 2023

Table 21. Ranking of field responses for institutional

Response in %	Institutional Category	Numerical Value
0-33	Not Effective Institutional	1
34-67	Limited Institutional	2
68 -100	Effective Institutional	3

Source: Author's Construct 2023

Table 22. Ranking of field responses for economy/finance

Response in %	Economy/Finance Category	Numerical Value
0-33	Weak economy	1
3467	A not-too-strong economy	2
68 -100	Strong economy	3

Source: Author's Construct 2023

Normalization of Field Responses. The third sub-step was converting field responses into pre-determined categories, with values ranging from 1 to 3. The final value for each parameter was determined by summarizing individual categories. The overall values for parameters are shown in Table 4.24, which were used to assess the adaptation capacity for elements at risk in all the wards.

Table 24. Overall adaptation capacity assessment for elements at risk of climate hazards

Adaptive capacity	Field responses (%)	Value category	Field response/100 x value
	Knowledge		
Not knowledgeable	52.5	2	1
Limited knowledge	35.8	2	0.7

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Available knowledge	11.7	1	0.1
Overall values			1.8
	Technology		
Not Available technology	28.6	1	0.3
Limited technology	50.5	2	1
Available technology	20.9	1	0.2
Overall values			1.5
	Economy/Finance		
Weak economy	52.4	2	1
Not too strong	47.6	2	1
Strong economy	0	1	0
Overall values			2
	Institutional		
Not Effective	25.8	1	0.3
Limited	58.5	2	1.2
Effective	15.7	1	0.2
Overall values			1.5

Source: Author's Construct 2023

Determination of Vulnerability Levels. The formula introduced for determining the vulnerability levels of the elements at risk of flooding in the Jangwani ward was used: LV = (HRR x ERR)/ACR.

The determination of the vulnerability levels involved eight sub-steps. This depends on the previous steps of climate hazards assessment, elements at risk assessment and adaptive capacity assessment. Determining the level of Vulnerability required identifying the type of hazards, hazards risk rating, elements at risk rating or potential impacts, adaptive capacity rating, ranking the level of vulnerabilities and results of the vulnerability assessment as in Table 25. The ranking of the levels of Vulnerability is as indicated in Table 25, noting 0 for no vulnerability, 1-1.5 for low Vulnerability, 1.6-2.5-medium Vulnerability, 2.6-3.5 for high Vulnerability and 3.6-5 for very high Vulnerability. The sub-steps and calculation of vulnerability levels are indicated in Table 4.26.

Table 25. Determination of vulnerability levels of elements at risk of flooding hazard.

Sub-step 1: Hazard	**Sub-step 2: Hazard risk rating (HRR)**	**Sub-step 3: Elements at risk (ER)**	**Sub-step 4: Elements at risk rating (ERR)**	**Sub-step 5: Adaptive capacity rating (ACR)**		**Sub-step 6:** $LV = \frac{HRR \times ERR}{ACR}$
Flooding	2.4	Social and economic activities and livelihoods	3	Knowledge	1.8	2.4 x 3/1.8 = 4
				Technology	1.5	2.4 x 3 /1.5 = 4.8
				Institutional	1.7	2.4 x 3 /1.7 = 4.2
				Economy / Finance	2	2.4 x 3/2 = 2.2
	2.4	Physical infrastructures	3	Knowledge	1.8	2.4 x 3/1.8 = 4
				Technology	1.5	2.4 x 3/1.5 = 4.8
				Institutional	1.7	2.4 x 3/1.7 = 4.2
				Economy / Finance	2	2.3 x 3/1.7 = 4.2
	2.4	Ecosystems	2.8	Knowledge	1.8	2.4 x 2.8/1.8 = 3.7
				Technology	1.5	2.4 x 2.8/1.5 = 4.5
				Institutional	1.7	2.4 x 2.8/1.7 = 4
				Economy / Finance	2	2.4 x 2.8/2 = 3.4

Source: 2023

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Table 26. Results of the vulnerability assessment for socioeconomic activities, physical infrastructures, and ecosystems as elements at risk to flooding hazards in Jangwani ward.

Element at Risk	Adaptive Capacity Rating		Sub-Step 7: Vulnerability Ranking 0-No Vulnerability 1-1.5-Low Vulnerability 1.6-2.5-Medium Vulnerability 2.6-3.5-High Vulnerability 3.6-5-Very High Vulnerability	8: Results of the Vulnerability
Social and economic activities and livelihoods	Knowledge	1.8	4	Very high Vulnerability
	Technology	1.5	4.8	Very high Vulnerability
	Institutional	1.7	4.2	Very high Vulnerability
	Economy / Finance	2	2.2	Medium Vulnerability
Physical infrastructures	Knowledge	1.8	4	Very high Vulnerability
	Technology	1.5	4.8	Very high Vulnerability
	Institutional	1.7	4.2	Very high Vulnerability
	Economy / Finance	2	4.2	Very high Vulnerability
Ecosystems	Knowledge	1.8	3.7	Very high Vulnerability
	Technology	1.5	4.5	Very high Vulnerability
	Institutional	1.7	4	Very high Vulnerability
	Economy / Finance	2	3.4	High Vulnerability

Source: Field data, 2021

The results of determining the level of Vulnerability 7 of elements at risk to climate hazards in the study area found that physical infrastructures determined very high Vulnerability to flooding hazards ranked at 4.8, 4.2 institutional, 4.2 economy/finance, and 4 knowledge. Socioeconomic activities and livelihoods were determined to have very high Vulnerability, ranked at 4.8 in technology and 4.2 in institutional. The ecosystems were determined to have very high Vulnerability, ranked at 4.5 technology, 4 institutional, and 3.7 knowledge, while economy/finance was determined as having high Vulnerability, ranked at 3.4. The high Vulnerability of physical infrastructures, socioeconomic activities, livelihoods, and ecosystems to flooding hazards was due to high exposure to flood-prone areas of Msimbazi Valley, leading to high sensitivity and high potential impacts on flooding hazards. This led to low adaptive capacity, which ranked at 1.8 for knowledge, 1.5 for technology, 1.7 for institutional, and 2 for economy/finance to combat flooding hazards. Araos (Araos et al., 2016) on climate change adaptation planning in large cities explored the need to strengthen adaptive capacity to climate change for reporting adaptation policies. The study on the constraints on climate change adaptation in a city with a large development deficit found that lack of adequate provision for infrastructure and services, including piped water, sewers, drains and solid waste collection, increases the Vulnerability of cities to climate change, but building institutional and financial capacity is critical for enhancing resilience to climate change impacts in urban areas (Kiunsi, 2013).

Further, a study on mainstreaming climate change adaptation planning in city master plans observed that inadequate mainstreaming of climate change adaptation in city master plans was due to inadequate capacity in terms of knowledge, technology, institutional and economy/finance for local authorities and therefore strengthening local capacity enhance the resilience of cities and sustainable cities and communities in urban areas (Nyashilu et al., 2023). Climate change vulnerability assessment informs planning for climate change adaptation by assessing the risks and

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impacts of climate change, creating a strategic framework for adaptation, developing interventions for resilience, and reducing Vulnerability (UN-Habitat, 2014, 2019). Moreover, a study on Nepal's climate change vulnerability assessment focused on assessing the Vulnerability to climate change hazards, namely floods, droughts and landslides in various sectors of agriculture, human settlements and infrastructure, forest and biodiversity, sanitation, energy, and solid waste (UN-Habitat, 2015). The study found that urgent policies and actions were needed to build resilience and mitigate the impacts of climate.

CONCLUSION

Cities in the Global South are vulnerable to climate change hazards, including urban flooding. Integrating vulnerability assessment in urban planning enhances cities' resilience to climate change-induced flooding. Variouareclimate change vulnerability assessment framework frameworks many disciplines, such as disaster management, health, agriculture, and forestry, but minor in urban planning. The results of determining the level of Vulnerability of elements at risk to climate hazards in the study area found that physical infrastructures, socioeconomic activities, and livelihoods were determined as very highly Vulnerable to flooding hazards, followed by ecosystems. The reasons for the very high Vulnerability of physical infrastructures, socioeconomic activities liv, livelihoods and ecosystems to flooding hazards were due to high exposure to flood-prone areas of Msimbazi valley, which led to high sensitivity and high potential impacts to flooding hazards. This has led to low adaptive capacity regarding knowledge, technology, institutional and economy/finance to adapt to climate change-induced flooding hazards.

The study recommends that mainstreaming climate change adaptation planning through the introduction of vulnerability assessment in the planning process and adaptation capacity development both knowledge, technology, institutional, economy and financial allocation in urban planning sectors is crucial for inclusive and sustainable cities and communities as per promoted by UN 2030 sustainable development goals 11 (sustainable cities and communities) and 13 (climate action), Agenda 2063 on Future Africa We Want, the Paris Agreement 2015, the New Urban Agenda 2016 and the Sendai Framework on the Disaster Risk Reduction 2015-2030 (Nyashilu et al., 2023). Conversely, the study recommends adopting the proposed new urban planning process indicated in Figure 15. The proposed urban planning process covers the phases of preparation, planning, implementation, monitoring, evaluation, and review. The preparation phase is the entry point for vulnerability assessment, which includes climate hazards, elements at risk, adaptation capacity assessment, and determination of the levels of vulnerabilities. The planning phase should consider the future risks of climate hazards such as temperature, rainfall, flooding, sea level rise, and coast erosion for climate-resilient human settlements and land use planning. The implementation phase should consider designing and implementing adaptation options. The monitoring, evaluation and review phase should consider adjusting objectives, goals and adaptation options and conducting periodic climate change vulnerability assessments. The periodic vulnerability assessment results assist in comparing whether the set adaptation options had reduced climate change vulnerability to elements at risk of climate hazards affecting the urban areas. M&E for climate change adaptation options explores the challenges, progress, and gaps associated with climate change by undertaking periodic vulnerability assessments. It is an effective way of monitoring and evaluating the adaptation actions in each system.

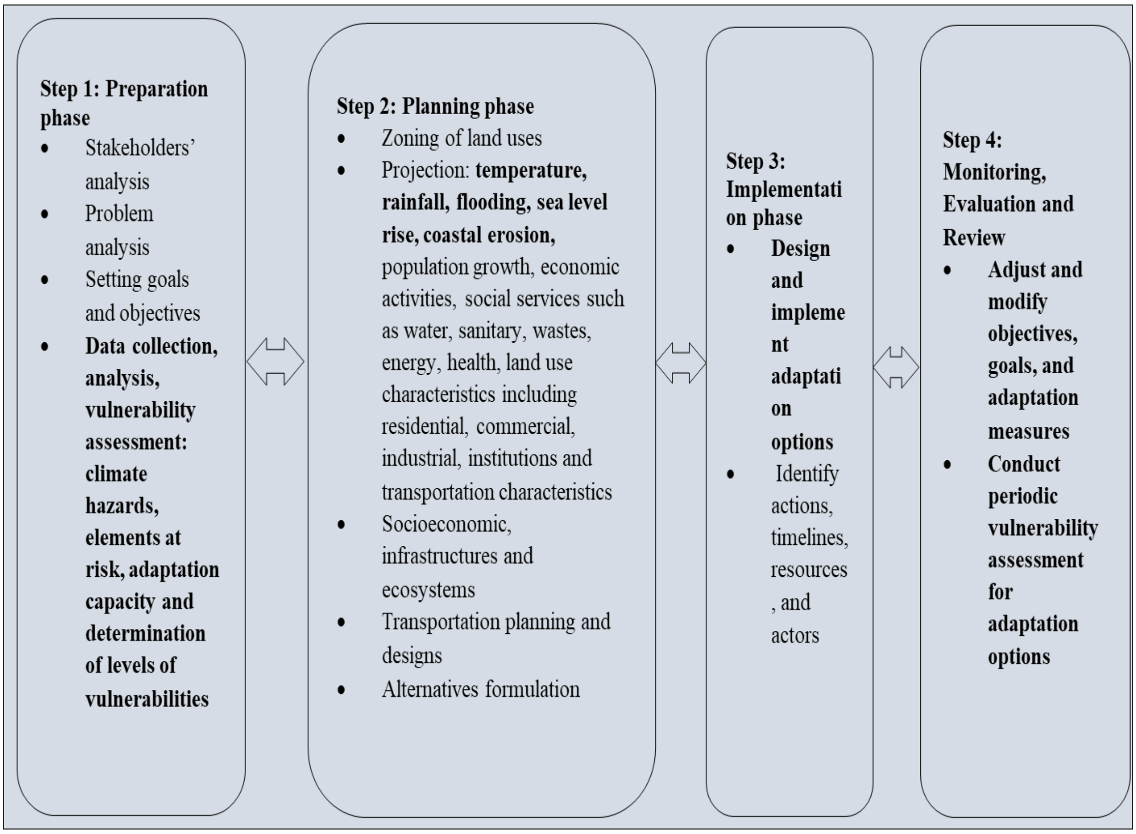

Figure 15. The proposed new urban planning process with climate change adaptation, 2023.

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